

# Brookhaven National Laboratory Smart Grid Test Facilities

*Sustainable Energy Technologies Department  
April 2016*



**BROOKHAVEN**  
NATIONAL LABORATORY

*a passion for discovery*



# Smart Grid development will present challenges that must be resolved

- Mitigating Renewable Variability
- Integration of DER
- Role of Energy Storage
- Application of Smart Inverters
- Data-based control schemes
- Application of advanced grid sensors

# BNL has access to two facilities that can support smart grid research

- Long Island Solar Farm (LISF)
  - High resolution data on renewable generation
- Northeast Solar Energy Research Center (NSERC)
  - Field testing of new smart grid technologies

# BNL has access to the Long Island Solar Farm ...

- 32 MWac grid-connected solar photovoltaic plant on BNL campus
  - Privately Owned
  - Purpose is to sell power to LIPA under a PPA
  - Commercial operation initiated Nov. 1, 2011
- Located on 195 acres on BNL campus under an easement from DOE
  - Consideration (in-kind funds) provided to DOE
  - BNL can instrument and collect data from the array for research purposes
- BNL installed research instruments to collect data for research
  - High-resolution (1-sec.), time stamped data sets



LISF began commercial operation November 1, 2011



# The LISF generates 32MW-ac of power for Long Island



# BNL installed research instruments in the LISF

## Collecting Time Synchronized, High Resolution (1sec.) Data Sets

### ■ Solar Resource Data

- Field Instruments: pyranometers 32 pairs @ 25 locations to measure direct and diffuse irradiance
- Base Station Instruments: Solar tracker, rotating shadowband radiometer for precision measurements



Rotating Shadowband Radiometer



Field Pyranometer

### ■ Meteorological Data

- Two Met Towers (85m & 10m)
  - Air Temp/Barometric Pressure
  - Wind speed and direction
- Array Field Instruments
  - Temperature (air, panel, soil)
  - Relative Humidity
- Total Sky Imagers – Cloud images



Power Quality Monitor



Pyrheliometer



Pyrgometer

### ■ Electrical Performance Data

- Power Quality: all inverters, collection substation
- Power Quality: Utility feeders to BNL
- String Level: DC currents and voltages



Sun tracker with sensors for global, diffuse and direct irradiance.



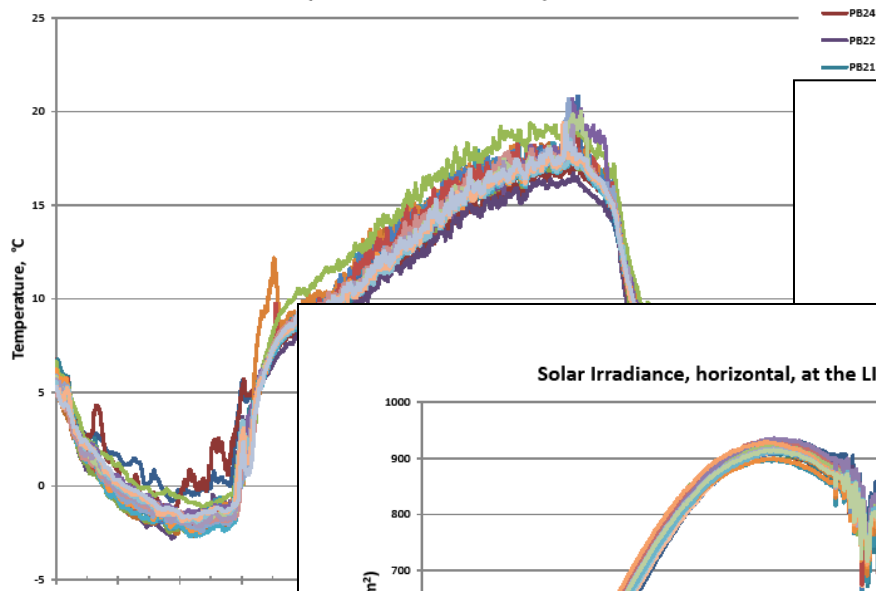
Total Sky Imager



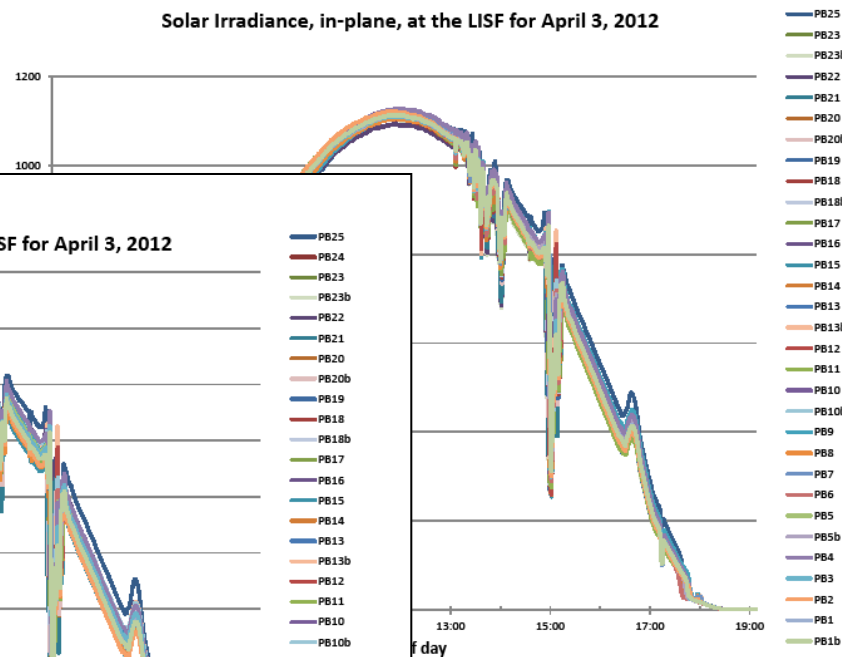
# BNL is collecting and storing LISF data

Data will be made available for research purposes

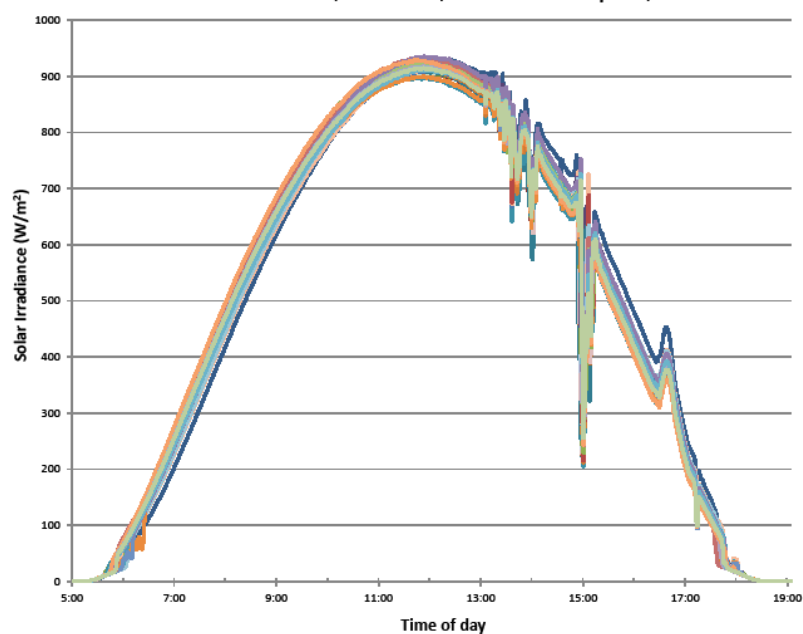
Air temperature at the LISF for April 3, 2012



Solar Irradiance, in-plane, at the LISF for April 3, 2012



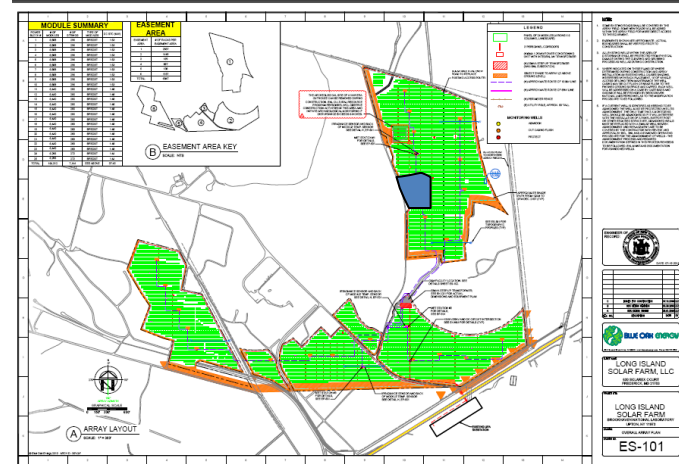
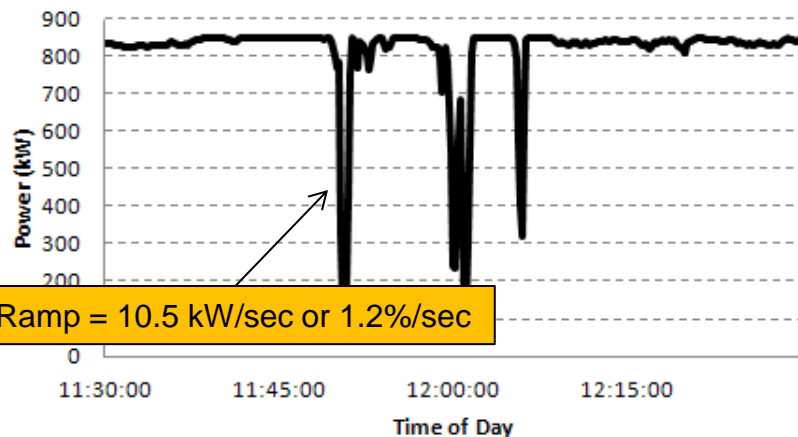
Solar Irradiance, horizontal, at the LISF for April 3, 2012



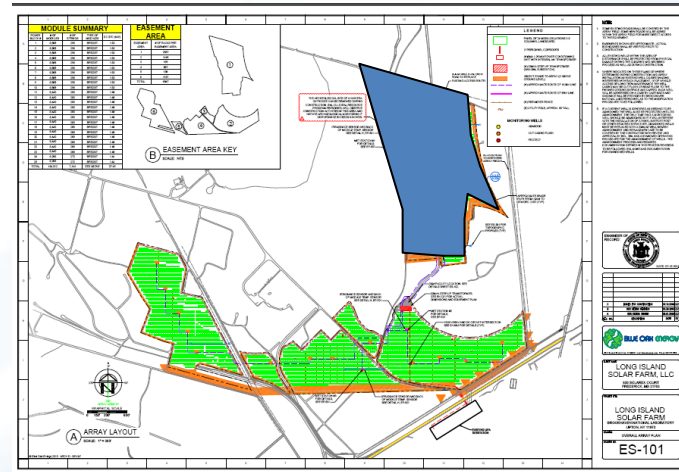
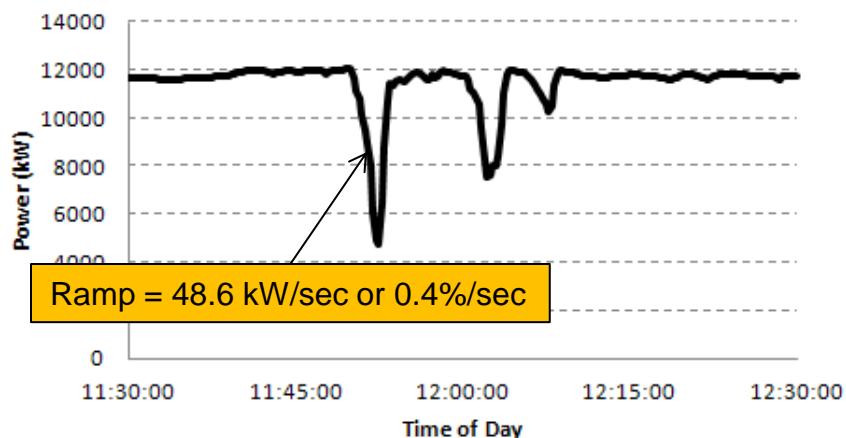
# Power Output and Ramps During Cloud Transients

(Power data from 1 power block and total for Area 1)

PB-05 Power vs. Time for January 7, 2013



Area 1 Power vs. Time for January 7, 2013





# BNL also has the Northeast Solar Energy Research Center (NSERC) on its campus

- Supplements LISF research
  - DOE owned facility on BNL campus
  - Available to support industry needs
- Comprised of two elements
  - Research array for field testing
  - Laboratories for standardized testing
- Resource for the Northeast
  - Field testing
  - Technology development test bed
- Solar array connected to BNL electrical system
  - Help with BNL sustainability goals
  - Enable micro-grid test bed

## NSERC Research Facility

- ✓ **Field Testing\***
- ✓ **Grid Integration**
- ✓ **Microgrid Demonstrations**
- ✓ **Smart Grid Test Bed**
- ✓ **Energy Storage**
- ✓ **Smart Grid Inverters**
- ✓ **Solar Forecasting**
- ✓ **Reliability & Degradation**
- ✓ **Environmental Sustainability**

**\* No UL Listing Required!**

## The research array design includes special features to facilitate research...

- Nominal Specifications

- Power output: ~1MW-ac
- Reconfigurable architecture
  - 67kw blocks
  - Voltage 1000V
- Solar Modules – Suniva crystalline silicon
  - ~16% efficiency
  - Buy American Compliant
- Racking: Northern States Metal
  - Fixed tilt (90%) /Single Axis trackers (10%)
- Inverters: Aurora Power One Modular
  - Capability for individual MPPT control of blocks

- Special Features

- Inverter testing from utility-scale to string level and micro inverters
- Storage systems – separate test pad provided
- Microgrid – ring bus architecture included
- Solar module testing – empty racks for module testing

From the world leading  
PV research lab comes  
sensible solar.

## SUNIVA OPTIMUS® SERIES MONOCRYSTALLINE SOLAR MODULES

### OPTXXX-60-4-100 (60 cell module)

The Optimus modules consist of Suniva's latest technology, ARTISS™ Select. These superior monocrystalline cells are designed and manufactured in the U.S.A., using our proprietary low-cost processing techniques. Engineered with our pioneering ion implantation technology, high power-density Optimus modules provide excellent value, performance and reliability.

#### Engineering Excellence

- Built exclusively with Suniva's highest-efficiency ARTISS Select cells, providing one of the highest power outputs per square meter at an affordable manufacturing cost
- Suniva's state-of-the-art manufacturing facility features the most advanced equipment and technology
- Suniva is a U.S.-based company spun out from the Georgia Tech University Center of Excellence in Photovoltaics (one of only two such research centers in the U.S.)

## PVI-400.0-TL

### GENERAL SPECIFICATIONS CENTRALIZED MODELS

PVI-400.0-TL is a compact transformerless solution for large scale PV plants. DC input voltage capability of up to 1000V offers array configuration flexibility and reduces cable losses. Industry-leading power conversion efficiency of 98% combined with a state of the art Maximum Power Point Tracking (MPPT) algorithm augments the total energy harvest to maximize energy yield.

This extremely scalable modular inverter system, based on 67kW modular blocks can be configured for single MPPT or multiple MPPT's to match unique plant configurations. Reduction of performance in any individual inverter block will not impact the energy-harvesting capabilities of other blocks. This superior modularity function increases the uptime and supports low mean time to recovery by enabling on-site replacement.

Higher input and output capabilities make the PVI-400.0-TL a perfect choice for utility projects. The inverter is delivered pre-configured and pre-tested, significantly reducing on-site wiring, testing and installation costs.

## Features

- Reduced susceptibility to a single fault. In case of a component failure, a maximum of 67kW will be lost
- Maximum input voltage of up to 1000Vdc for utility scale PV plants
- Maximum efficiency of 98% and CEC efficiency of 97.5% ensure more power is fed into the grid
- Fully equipped to connect to an external MV transformer
- Can be configured as Multi-Master, Master-Slave, and Multi-Master-Slave as per project requirement
- Integrated AC circuit breaker provides protection against overload and short circuit faults on the AC output side
- Each 67 kW block has an integrated DC disconnect in addition to input/output protection equipment (fuses and OVR)
- Reverse-polarity protection minimizes potential damage caused by array mis-wiring
- Easy installation and maintenance procedure. Front extractable DC/AC converters and accessibility to all critical parts
- Two independent RS-485 communication interfaces for inverter and intelligent string combiner monitoring
- Compliant to IEEE 1547 Standards for grid connection

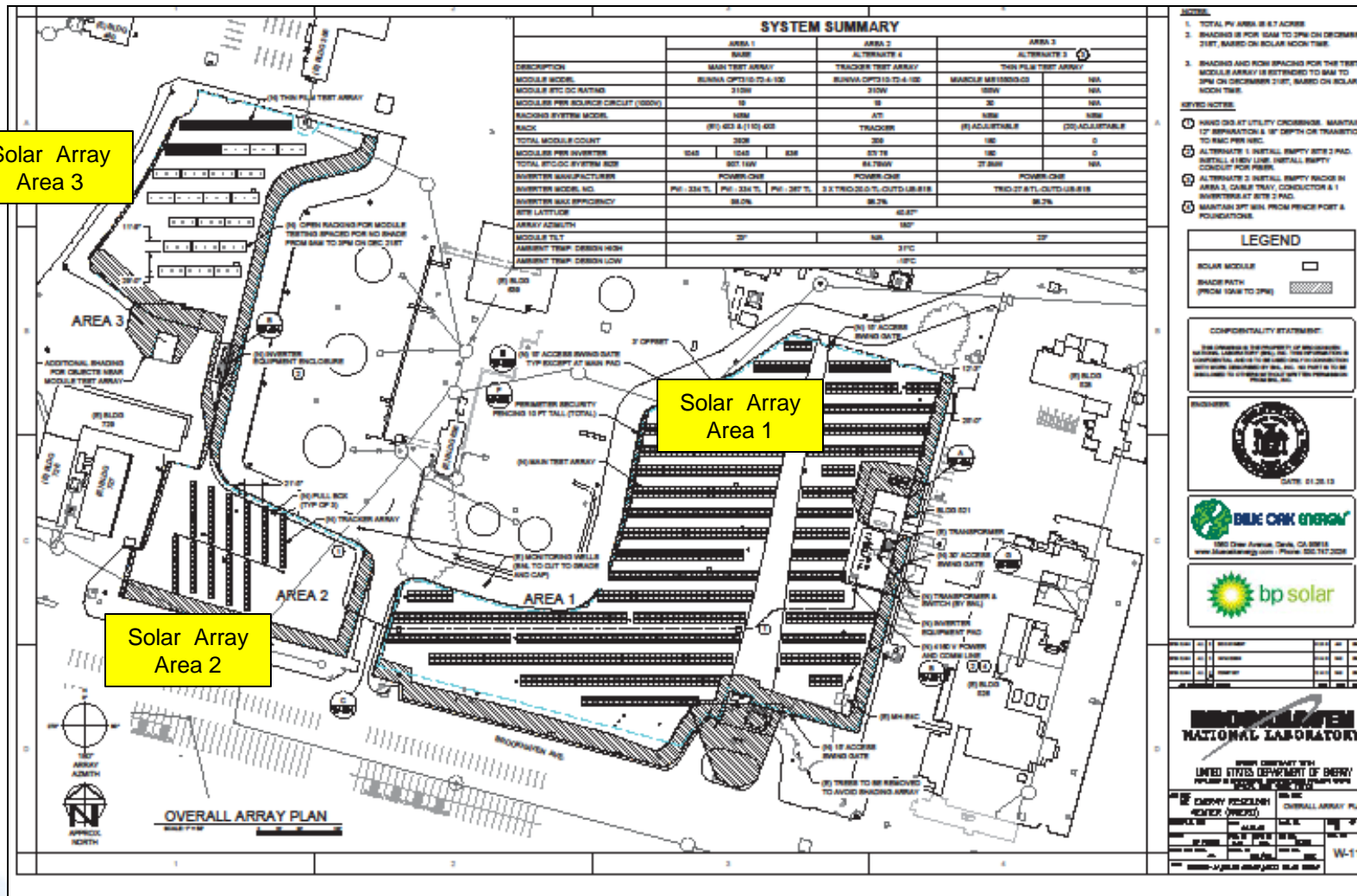
# AURORA

AURORA PLUS

AURORA PLUS

1

Solar Array  
Area 3



Area 1: ~907kw-dc for testing inverters, storage and micro-grids – and provide power to BNL  
Area 2: ~ 65kw-dc for testing modules on trackers  
Area 3: ~150kw-dc for testing new module designs and inverter topologies



# The first 518kW-dc section of NSERC is operational



SCADA System & Data Historian

## Suniva solar modules

- 310W/45.7Voc/9.06Isc
- 16.5% Efficiency
- 1,672 panels, 518kWdc

## Power One Inverters

- 67kW blocks/ individual MPPT
- 98% Efficiency

## Array is Operational

- Build: August 2013 to May 2014
- Power to BNL: May 21, 2014



Fixed-tilt Solar Modules



Ring Bus Switchgear



Equipment Test Pad



Above Ground Cable Trays



# NSERC will be used as a research facility for advancing Smart Grid technologies and renewables integration

- Field Testing for Deployment of New Technologies
  - Evaluation and testing of new design concepts, such as inverters with capability for voltage and VAR control
  - Comparison of performance for components and systems using different technologies
- Smart Grid Integration Studies
  - Strategies to improve communication and control
  - Techniques for integrating large numbers of systems into utility grids
- Energy Storage Research
  - Value propositions for integrated grid-level storage
  - Evaluation of storage and control alternatives
  - Reduce intermittency, resource extension
  - Frequency regulation capability
- Reliability and Degradation Studies
  - Bankability testing for new technologies – similar to Regional Test Centers
  - Long-term reliability and degradation studies
  - Standardized test conditions to evaluate component degradation
  - Post mortem testing and failure analyses

**No UL Listing  
or  
interconnect  
Permits  
required!**

## Contact for Additional Information

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